unattained limiting value is not new-fangled, it appears worth while to quote a few words of the paper of Gauss, above referred to, which is of date 1799.

"Ex suppositione, X obtinere posse valorem S neque vero valorem Π, nondum sequitur, inter S et Π necessario valorem T jacere, quem X attingere sed non superare possit. Superest adhuc alius casus: scilicet fieri posset, ut inter S et Π limes situs sit, ad quem accedere quidem quam prope velis possit X, ipsum vero nihilominus nunquam attingere."

It is a curious enough fact of history that it is Weierstrass's use of this principle which has destroyed the Dirichlet proof of a fundamental theorem of the theory of potential (Thomson and Tait's "Natural Philosophy," 1879, vol. i., first line of p. 171). H. F. BAKER.

Cambridge, January 23.

The Aurora of September 9, 1898.

I OBSERVE, from NATURE, that an auroral display was visible in the South of England on the evening of September 9. It may interest some of your readers to know that an aurora was seen here on the evening of September 10. The display began at about a quarter to eight o'clock, and lasted for an hour or so. The whole southern heavens at first became suffused with a bright orange light low down upon the horizon, from which a few streamers issued from time to time, rising (judging by the eye) to a height of, say, 45 degrees above the horizon. When both glow and streamers had faded away, I noticed three luminous clouds, one at the zenith. The largest of these clouds increased in size, and shot forth a few streamers of light, both upwards and downwards, and all then disappeared. I have witnessed several auroral displays at Ashburton, but none like that of September 10, the distinguishing features of which were the orange glow and the luminous clouds.

On the following day, my telephone, which had never failed me before, worked irregularly, and some of the other telephones in the town were similarly affected. CHAS. W. PURNELL.

Ashburton, Canterbury, N.Z., December 21, 1898.

THE APPLICATION OF PHOTOGRAPHY TO THE STUDY OF THE MANOMETRIC FLAME.

THERE are few more beautiful phenomena in experimental physics than those presented by the image of the manometric flame as one sees it in the revolving mirror. Especially is this true when the flame is excited by means of the complex tones of the human voice or by some musical instrument such as the violin, which possesses pronounced and varying tone colour.

Little use, nevertheless, has been made of the flame as an implement in research. Indeed the whole of the early literature pertaining to the manometric flame may be said to consist of the three papers[1] in which, at intervals of ten years, Rudolph Koenig described the apparatus which he first made public at the London Exhibition of 1862, together with the various experiments to which it was adapted. The writers of text-books, it is true, have made free use of Koenig's beautiful method, but investigators have been slow to avail themselves of it. The use of sensitive flames in the stroboscopic study of vibrations by Toepler (*Poggendorff's Annalen*, vol. cxxviii. p. 108, 1866), which method has since been employed by Brockmann (*Wiedemann's Annalen*, vol. xxxi. p. 78, 1887) in his analysis of the movement of the air in organ-pipes, and also the observations of singing and of sensitive flames by Kundt (*Poggendorff's Annalen*, vol. cxxviii. p. 337 and p. 614, 1866); by Barrett (*Philosophical Magazine*, 1867); and by Tyndall ("On Sound," Lecture vi., 1867), belong to this period. These researches, however, form a class by themselves, and are to be traced back to the earlier work of Higgins (1777), Chladin (1802), De la Rive (1802), Faraday (1818), Wheatstone (1832), Schaffgotsch (1857), and Le Conte (1858). In them the use of the manometric capsule does not occur, and they appear, from first to last, to be entirely independent of the work of Koenig.

The difficulty of securing a trustworthy record of the forms taken on by the flame-image has doubtless had much to do with this hesitancy. The drawings published by Koenig to accompany the description of his experiments are of great beauty, and the more intimately one is acquainted with the appearance of the flame-image itself, the more one is impressed with the extraordinary fidelity of these representations of it. The secret of their accuracy is to be found in the method by which they were obtained, which is described by Koenig in the article of 1872, to which reference has already been made. In the preparation of the well-known plate of the drawings of flame-images corresponding to the five principal vowel sounds, which was exhibited at the annual meeting of German Men of Science (*Naturforscherversammlung*, Dresden, 1868) each vowel was sung at a carefully ascertained pitch, and duplicate drawings were made by Koenig himself and by a draughtsman employed for that purpose. When these two drawings were found to be alike they were assumed to be correct, but wherever a variation occurred the experiment was repeated until the two were brought into agreement. Each vowel was sounded with a pitch corresponding to each note of the scale between ut_1 and ut_3, so that seventy-five of these drawings, perfected by many repetitions, appear in this one plate.

The most complicated of the pictures of the manometric flame drawn by Koenig is that shown in Fig. 1,

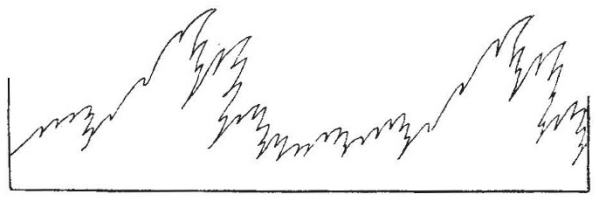

FIG. 1.—Drawing of a manometric flame (after Koenig).

in which an attempt is made to record the motions of the flame when the tongue is going through the vibrations necessary to produce the rolling sound of the German *r*, but without permitting the vowel-producing qualities of the voice to accompany it. Doubtless the difficulty of securing records by the method of free-hand sketching, which had been employed by Koenig, to say nothing of the difficulty of interpreting the more complicated forms assumed by the flame-image, has prevented the general introduction of what in other respects is a very attractive method of research.

In 1886 the question, which must have occurred to many observers of the manometric flame, whether these fleeting flame-images could be photographed, was answered affirmatively by Doumer (*Comptes rendus*, vol. ciii. p. 340; vol. cv. p. 1247), who used such photographs in the determination of pitch and of the phase relations of sound waves. Doumer, however, published none of his photographs; so that we do not know what degree of success he attained. In 1893 Merritt, who was at that time unacquainted with Doumer's experiments, undertook the photography of the manometric flame in the hope of thus developing a method which would be of use in connection with certain studies in phonetics. His paper, entitled "A Method of Photographing the Manometric Flame, with Applications to the Study of the Vowel A" (*Physical Review*, vol. i. p. 166), contains the first published photographs of the Koenig flame-images. Merritt found it barely possible to photograph, upon a rapidly moving plate, the flame produced by the ordinary Koenig apparatus. The actinic weakness of the flame

[1] Koenig: *Poggendorff's Annalen*, vol. cxxii. p. 242; vol. cxlvi. p. 161; "Quelques Expériences d'Acoustique," Chapter vii.

was such that the development of the under-exposed plates was exceedingly laborious, and the results were most unsatisfactory. He turned his attention, therefore, to increasing the actinic effect by the use of a burner in which the flame, at first of ordinary illuminating gas, was surrounded by pure oxygen. With this form of burner, a diagram of which is given in Fig. 2, photographs were readily obtained upon a moving plate, in which the salient features of the images described by Koenig were clearly brought out. The gas was subsequently enriched by passing it through a receiver of petroleum ether, and in this way the brilliancy of the flame was further greatly increased. In Merritt's experiments the moving plate was shot horizontally through the field of the camera at a speed sufficient to separate properly the various flame-images. The speed of the plate-holder, which was arranged to slide between guides, was about two metres per second. The entire time-period covered by the chrono-photographs thus produced was only a few hundredths of a second.

Chrono-photographs of the manometric flame have since been made by Hallock and Muckey (*The Looker On*, 1896, pp. 1, 177 and 375, 1896), who used such flames, excited by resonators, in the analysis of the voices of various opera singers; by the writer in collaboration with Prof. Merritt (*Physical Review*, vol. vii. p. 93, 1897),

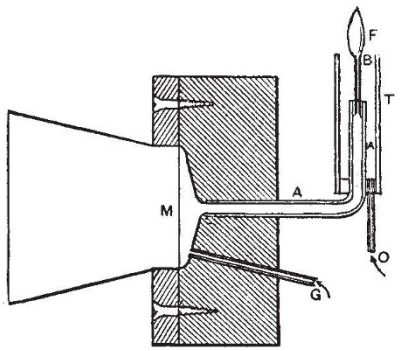

FIG. 2.—Merritt's burner [the diaphragm is at M; illuminating gas enters at G; oxygen at O].

and by Miss J. A. Holmes (*Thesis*—in manuscript—Library of Cornell University, 1898).

Acetylene gas, which has come into common use since the experiments just described were made, affords a light of much greater actinic power than any which was formerly available. The flame of burning magnesium alone surpasses that of acetylene in brilliancy. The carbon bands in the electric arc, to be sure, give that source of light, likewise higher actinic value than the acetylene flame; but the arc light cannot be used manometrically, nor, indeed, is it probable that the magnesium flame could be thus employed.

When we surround the acetylene flame with pure oxygen in a burner, like that described by Prof. Merritt, its actinic power is still further increased.

In 1897 the writer spent many pleasant hours of the summer vacation with Prof. Merritt in the fascinating work of photographing the manometric flame. The experiments of 1893 were repeated with acetylene in place of ordinary enriched burning gas, and with films of considerable length instead of the glass plates. The manometric burner was the same in all essential features as that described by Merritt in the article which I have just cited. It was supplied with a mixture of equal volumes of acetylene gas, generated by the action of water upon calcium carbide in the usual manner, and of hydrogen. The chrono-photographs were taken upon films 120 cm. in length, which for convenient handling were mounted in an especially constructed camera. This camera consisted of the usual lens and bellows, and of a rectangular box of wood containing a drum D (Fig. 3), upon the periphery of which the film was mounted. The drum could be driven at a convenient speed, either by means of a belt attached to an electric motor, as shown in the diagram, or, as was sometimes found to be more convenient, by hand. The box which contained the drum was light-tight, excepting that at a position suitable to allow the passage of the rays from the lens there was a vertical slit closed by a shutter. This shutter could be opened electrically by an observer stationed at the manometric flame, after which it remained open for precisely one revolution of the drum. When this revolution was completed, the shutter closed automatically.

The revolving drum, which carried the sensitised film upon which the photographs of the flame were taken, was given a speed in most of our experiments of about one revolution per second. This was found to be quite sufficient for the proper separation of the flame-images. and it permitted us to record upon a single film any word or phrase the utterance of which did not require more than a second of time. In certain cases, where we desired to include in the chrono-photograph poly-syllabic words or phrases, the speed was somewhat reduced; in other cases, for the purpose of a further separation of the flame-images, the drum was driven at a much higher velocity.

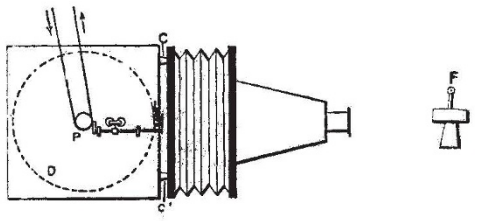

FIG. 3.—Camera for photographing the manometric flame. [The flame is at F; the revolving drum is represented by the dotted circle D.]

In the manner just described a large number of striking photographs were obtained, the beauty and sharpness of detail of which no adequate idea can be given in the printed reproduction. It was found that the repetition of the same combination of articulate sounds, uttered at the same pitch and by the same speaker, always gave very closely indeed the same series of flame-images. Nevertheless the reading and interpretation of these photographic representations of the manometric flame is by no means a simple matter. When we attempt to read such a record, as one would read the trace of the syphon recorder in a telegraphic message, or as one would read shorthand, we find that it is only the vowels which produce any marked agitation of the flame. All those accompanying mouth-sounds which introduce and close each syllable in articulate speech, and by which, in great measure, we are able to distinguish the different words, produce a very feeble and often an unrecognisable effect upon the flame. The records are indeed the very opposite of shorthand writing, not only in that instead of a single character to a syllable, we have sometimes as many as a hundred oscillations of the flame, but likewise in the fact that while shorthand is made up of words with the vowels left out, these manometric photographs represent speech with the consonants suppressed. It is obvious that to read a record of the latter sort, even after the eye had been trained to recognise the flame-groupings characteristic of all the vowel sounds, is more difficult than it is to pick out words in which the consonants are indicated and the vowels omitted.

There is in the interpretation of the flame photographs

a further difficulty which is clearly brought out in the famous chart of drawings exhibited by Koenig in 1867. This difficulty is due to the fact that the characteristic grouping for each vowel differs with the pitch at which the sound is uttered, and that no two speakers sound the vowels in precisely the same manner, each one having his personal peculiarities of voice. Fortunately it is not necessary to learn to read them in this way, since their interest lies chiefly in the completeness with which they serve to show a multitude of details and peculiarities of articulate speech, which cannot be so directly studied in any other manner.

Not only are the subtle differences which distinguish the vowel sounds uttered by persons speaking various dialects manifested by differences in the flame groupings, but, as I have just pointed out, the individual peculiarities in the utterance of different speakers using the same dialect are plainly discernible. We have, moreover, in the record of each individual syllable, most interesting evidence of the gradual formation of the full vowel sound as the mouth opens at the beginning of the syllable, and the modification of the sound again as the mouth closes at the end. Another peculiarity which the reader of the manometric records encounters, lies in the fact that the pauses between words in ordinary speech are often of no greater duration than pauses between syllables of the same word. There is thus no way of separating words from one another until the record has been interpreted, and each group of flame-images has been assigned its place in the phrase. This difficulty is akin to the one with which we meet when, with unaccustomed ears, we try to distinguish for the first time the spoken words of a foreign language. The flame record does, on the other hand, for the reader what the printed page does not do. It shows clearly by means of the strength of oscillation into which the flame is thrown, which syllables are accented and which are unaccented by the speaker; and more than this, it is capable of indicating the degree of emphasis placed upon each syllable, and of recording faithfully those only too numerous cases in which we slur over, in careless speech, portions of a word which should perhaps be clearly enunciated.

It is unfortunately not possible to illustrate these points of interest without the use of very large plates. To show properly the record of a word or phrase containing four syllables, the photograph must be at least one metre in length. It is only possible to clip here and there an interesting passage from the records by way of illustration of the appearance of the photographs which may be obtained. These passages are of necessity very brief, covering a time interval in each case of less than two-tenths of a second. One cannot even give the record of a single complete, deliberately spoken syllable upon a plate of the width of a page of NATURE.

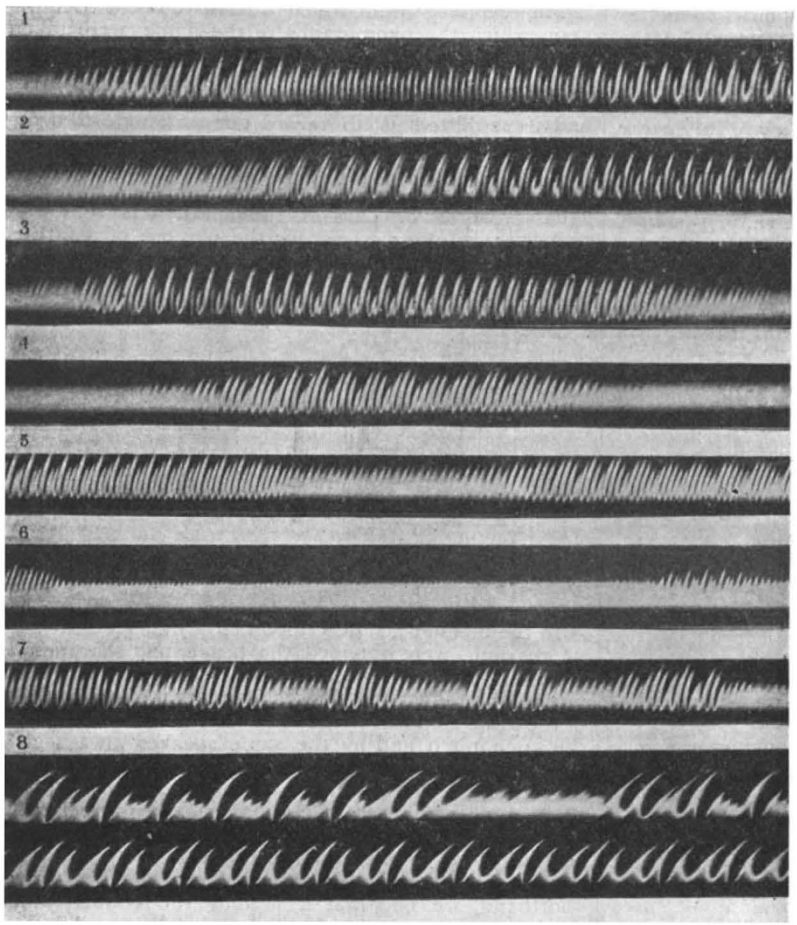

FIG. 4.—Specimens of chrono-photographs of the manometric flame. [The original width has been reduced by one-third.]

The photograph numbered 1 in Fig. 4 is the first part of the record obtained when the syllable *dā* (as in dart) is deliberately spoken. It shows the gradual formation of the serrated image as the mouth opens, which reaches its maximum of strength immediately thereafter. This is followed by a short interval, which may be called the *interval of adjustment*, during which the mouth is being brought into a position to utter the vowel properly. At the extreme right-hand the first vibrations due to the fully-developed vowel sound are to be seen. This photograph gives about one-third of the complete record obtained from such a syllable.

No. 2 shows in like manner the formation of the syllable *ah*, deliberately spoken, in which the mouth opens more slowly and the formation of the vowel is preceded by a characteristically different set of flame groupings. This trace is likewise cut off for lack of space, so as to show only the first third of the syllable.

No. 3 shows the whole of an accented syllable in a rapidly spoken word. The word in this case was *preposterous*, and the syllable selected for illustration here is the antepenultimate *pos*.

No. 4 shows a syllable still further shortened by rapidity of speech, namely *tan* at the end of the word *Raritan*.

No. 5 is a small portion cut from the middle of the record obtained from the word *river*. It is introduced into the plate for the purpose of showing the partial interruption of the vibrations due to the sounding of the *v* in the middle of this word. It is interesting to note likewise the gradual modification of the vowel sounds before and after *v* as the mouth closes and opens again.

The interruption due to this consonant is probably the least marked of any. The pronunciation of *b*, *d*, *t* and other consonant elements in the middle of words usually causes a more or less complete cessation of oscillations on the part of the flame for a considerable period of time.

No. 6 shows the record for the ending of the word *doctor*, spoken hurriedly. The photograph shows the behaviour of the flame from the moment when the first vowel sound is just being cut off by the closing of the mouth for the enunciation of that portion of the word represented by the letters *ct*. The whole of the last syllable, which is almost completely suppressed and slurred over, as is too often the case in every-day speech, is shown. The period of quiescence in this instance is greater than that which takes place between the successive words of a sentence spoken in the ordinary manner. This peculiarity has already been referred to in a previous paragraph.

No. 7 is a portion of the photographic record of the word *Raritan*, comprising the closing vibrations due to the first vowel sound *a* and the transition of this into the form of the rolling *r* which follows. The letter *r* was given a much stronger roll in speaking this word than is customary in English, for the purpose of studying the flame record thus obtained. Each contact of the tongue to the roof of the mouth in the production of the trill is shown in the flame record by a partial blotting-out of the serrated image.

No. 8 shows the results obtained when the speed of the film was increased to five metres per second. The upper line of flame-images is that obtained from a continuously sounded rolling *r*. It is possible in this instance to show only the details of a single member of the series of trills which make up this complex sound. The lower record, which was taken upon the same film and at the same speed, is that of the vowel *a* flat (as in cat) continuously sounded throughout the entire revolution.

It is the writer's opinion that very interesting and possibly important results might be obtained by the use of longer films driven at even higher rates of speed. There are indications, in certain of the photographs obtained in the course of the experiments just described, of vibrations of higher pitch, which are not properly separated from one another even at the speed of five metres per second.

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THE STUDY OF TROPICAL DISEASES.

THE *Geographical Journal* for December contains an interesting monograph, by Dr. Wistenra Sambon, upon the acclimatisation of Europeans in tropical lands. The subject-matter of this paper was discussed at the Royal Geographical Society last April, and various opinions were expressed upon it. Dr. Sambon is, further, the author of other communications dealing with this question. Put briefly, his contention is that there is nothing inimical to Europeans in tropical climates which cannot be prevented by hygienic measures. The two main characteristics of the tropical climate, viz. heat and moisture, are practically never *per se* the cause of disease, nor do they *per se* cause any deterioration in either the colonists themselves or their progeny. The mass of the so-called diseases of tropical climates has a parasitic origin. The enormous number of deaths from malaria in the unhealthy regions of Africa, and from snake-bite in India, are quoted by the author as examples of this. Even heat-stroke is, according to him, of parasitic origin. Further, not only is the great enemy to colonisation after actual occupation, the microbe, but the same agency comprises the great difficulty in colonisation. For instance, in the French Expedition to Madagascar in 1896, only seven men were killed by Hovas, and ninety-four wounded; the deaths due to pathogenic micro-organisms numbered 6000, and the sick list from the same cause 15,000. From these facts the contention is that all we have to do in order to make Europeans thrive in the tropics, is to exterminate the pathogenic micro-organisms which are the cause of so-called tropical disease; these once subjugated, and Europeans could live in the tropics like natives.

How this is to be done is naturally the difficulty. In the case of the malarial parasite, for instance, should we set about producing immunity, or destroying the parasite in the most exposed phase of its life-history? The latter method is the one which recommends itself as being, if the most difficult, at the least the most radical; hence the importance of the minute study of the life-history of each pathogenic parasite.

To render Europeans capable of supplanting natives in tropical countries is more, as Sir Harry Johnston pointed out, than we want. The desideratum is to render a relatively small number of Europeans capable of ruling the tropics. The limited knowledge we now possess of the means of curing tuberculosis, and of exterminating the tubercle bacillus, even although some of our best workers and thinkers have devoted themselves to the subject for more than a quarter of a century, prevents the most sanguine of us from expecting that the means of exterminating the malarial parasite will be hit in the immediate future. In spite, however, of this, no one can legitimately doubt that the careful study of the life-history of the parasite, and the nature of the so-called predisposition to malaria, will avail much in lowering the European death rate in the malarial regions of the tropics.

In this connection, it is interesting to note that there will, before long, be established in London an institution for the study of tropical disease. This institute will have a double function, viz. education and research. Use will be made of the clinical material of the port of London for teaching qualified medical practitioners who, either as members of the Government services, or as private individuals, intend practising in the tropics. In addition, research work upon the nature and causation of tropical disease will be undertaken and encouraged. The founding of this institution, as is invariably the case, has not been free from difficulties. Some of these, if not all, are probably by this time well known to the public, as, after a preliminary statement of grievances in the medical press, a lively correspondence has been devoted to this subject in the *Times*.

The site of the institute has been fixed at the branch hospital of the Seamen's Hospital Society, between the Royal Victoria and the Albert Docks. Upon the school buildings and enlargement of the hospital 13,000*l*. is to be spent, towards which the Colonial Office contributes 3350*l*. The maintenance of the school and the additional beds is estimated at 3050*l*. per annum, of which 1000*l*. will be paid annually by the Colonial Office in fees for the instruction of its students. The curriculum to be followed at the schools is to be arranged by a committee of experts.

The opposition to the scheme chiefly arises from three sources. The established medical schools, or rather their representatives, say that, both with regard to clinical material and laboratory accommodation, there is no need to go to the expense of building and instituting a new school. The staff of the Dreadnought Seaman's Hospital, of which the hospital which is to be metamorphosed into the new school is a branch, agree in the main, and emphasise the incongruity of choosing a relatively small hospital to the exclusion of the parent hospital and its staff. A third class of opposition, which may be described as unattached, appears in the form